Active Power Filter for Renewable Power Generation System with Buck-Boost Converter using Predictive Control Algorithm

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Abstract: An active power filter implemented with a fourleg voltage-source inverter using a predictive control scheme is presented. The active power filter is used to compensate the reactive power, reduce current harmonics and voltage distortions in the power system. The active power filter deliver better performances in the high voltage non linear load compensation. Renewable energy with Buck-boost converter is used to balance the dc link voltage. The predictive controller use to advance the performance of the active power filter, especially during transient operating conditions, because it can speedily follow the current–reference signal while maintaining a constant dc voltage.

Keywords: Active power filter, current control, four-leg converters, predictive control

I. INTRODUCTION

Increasing global energy consumption and noticeable environmental pollution are making renewable energy more important. Today, a small percentage of total global energy comes from renewable sources, mainly hydro and wind power. As more countries try to reduce greenhouse gas (GHG) emissions, new power generation capacity canno longer be met by traditional methods such as burning coal, oil, natural gas, etc. However, these DG units produce a wide range of voltages [1] due to the fluctuation of energy resources and impose stringent requirements for the inverter topologies and controls. To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind, biomass, hydro, co-generation, etc. In sustainable energy system, energy conservation and the use of renewable source are the key paradigm. The need to integrate the renewable energy like wind energy/PV into power system is to make it possible to minimize the environmental impact on conventional plant [1].

The integration of wind energy into existing power system presents technical challenges and that requires consideration of voltage regulation, stability, power quality problems. The power quality is an essential customer-focused measure and is greatly affected by the operation of a distribution and transmission network. The issue of power quality is of great importance to the wind turbine [2]. There has been an extensive growth and quick development in the exploitation of wind energy in recent years. Although active power filters implemented with three-phase four-leg voltage-source inverters (4L-VSI) have already been presented in the technical literature [2]–[6], the primary contribution of this paper is a predictive control algorithm designed and implemented specifically for this application. Traditionally, active power filters have been controlled using pre-tuned controllers, such as PI-type or adaptive, for the current as well as for the dc-voltage loops [7], [8]. PI controllers must be designed based on the equivalent linear model, while predictive controllers use the nonlinear model, which is closer to real operating conditions. An accurate model obtained using predictive controllers improves the performance of the active power filter, especially during transient operating conditions, because it can quickly follow the current-reference signal while maintaining a constant dcvoltage. So far, implementations of predictive control in power converters have been used mainly in induction motor drives [9]–[16]. Conventionally, PI, PD and PID controller are most popular controllers and widely used in most power electronic appliances.

This paper presents the mathematical model of the 4L-VSI and the principles of operation of the proposed predictive control scheme, including the design procedure. The complete description of the selected current reference generator implemented in the active power filter is also presented.

II. BACKGROUND WORKS

It consists of various types of power generation units and different types of loads. Renewable sources, such as wind and sunlight, are typically used to generate electricity for residential users and small industries. Both types of power generation use ac/ac and dc/ac static PWM converters for voltage conversion and battery banks for long term energy storage. These converters perform maximum power point tracking to extract the maximum energy possible from wind and sun. The electrical energy consumption behavior is random and unpredictable, and therefore, it may be single- or three-phase, balanced or unbalanced, and linear or nonlinear. An active power filter is connected in parallel at the point of common coupling to compensate current harmonics, current unbalance, and reactive power. It is composed by an electrolytic capacitor, a four-leg PWM converter, and a first-order output ripple filter, This circuit considers the power system equivalent impedance Z_s , the converter output ripple filter impedance Z_f , and the load impedance Z_f . The four-leg PWM converter topology is shown in Figure. This converter topology is similarto the conventional three-phase converter with the fourth leg connected to the neutral bus of the system. The fourth leg increases switching states from 8 to 16, improving control flexibility and output voltage quality, and is suitable for current unbalanced compensation. A dq-based current reference generator scheme is used to obtain the active power filter current reference signals. This scheme presents a fast and accurate signal tracking capability. This characteristic avoids voltage fluctuations that deteriorate the current reference signal affecting compensation performance. The current reference signals are obtained from the corresponding load currents as shown in Figure. This module calculates the reference signal currents required by the converter to compensate reactive power, current harmonic, and current imbalance.

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III. SYSTEM CONFIGURATION

The block diagram of the proposed digital predictive current control scheme is shown in Fig. 1. This control scheme is basicallyan optimization algorithm and, therefore, it has to be implemented in a microprocessor. Consequently, the analysis has to be developed using discrete mathematics in order to consider additional restrictions such as time delays and approximation.

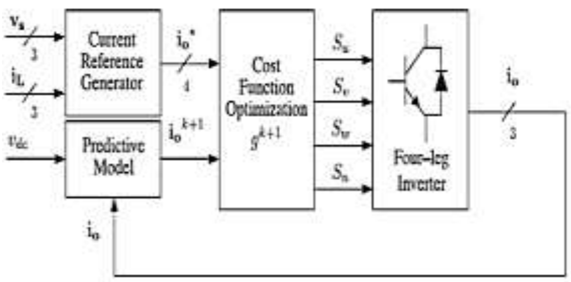

Fig. 1. Proposed predictive digital current control block diagram

The predictive control algorithm is easy to implement and to understand, and it can be implemented with three main blocks, as shown in Fig. 1.

1) Current Reference Generator: This unit is designed to generate the required current reference that is used to compensate the undesirable load current components. In this case, the system voltages, the load currents, and the dc-voltage converter are measured, while the neutral output current and neutral load current are generated directly from these signals (IV).

2) Prediction Model: The converter model is used to predict the output converter current. Since the controller operates in discrete time, both the controller and the system model must be represented in a discrete time domain [22]. The discrete time model consists of a recursive matrix equation that represents this prediction system.

A. DC Link Voltage Control

The dc-voltage converter is controlled with a traditional PI controller. This is an important issue in the evaluation, since the cost function is designed using only current references, in order to avoid the use of weighting factors. Generally, these weighting factors are obtained experimentally, and they are not well defined when different operating conditions are required. Additionally, the slow dynamic response of the voltage across the electrolytic capacitor does not affect the current transient response. For this reason, the PI controller represents a simple and effective alternative for the dc-voltage control. The dc-voltage remains constant (with a minimum value of sqrt of 6vs(rms)) until the active power absorbed by the converter decreases to a level where it is unable to compensate for its losses. The active power absorbed by the converter is controlled by adjusting the amplitude of the active power reference signal ie , which is in phase with each phase voltage. In the block diagram shown in Fig. 4, the dc-voltage vdc is measured and then compared with a constant reference value v*dc. The error (e) is processed by a PI controller, with two gains, Kp and Ti . Both gains are calculated according to the dynamic response requirement. Fig.2 shows that the output of the PI controller is fed to the dc-voltage transfer function Gs which is represented by a first-order system.

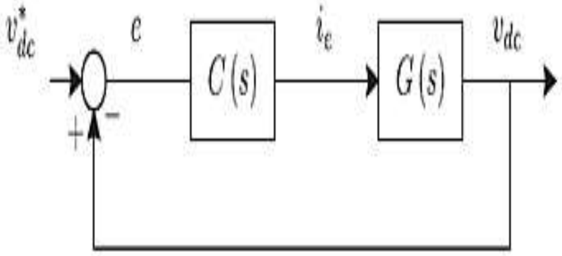

Fig.2. DC-voltage control block diagram.

IV. SIMULATION RESULTS

The compensation effectiveness of the active powerfilter is corroborated in a 2 kVA experimental setup. A six-pulse rectifier was selected as a nonlinear load in order to verify the effectiveness of the current harmonic compensation. A step loadchange was applied to evaluate the transient response of the dc-voltage loop. Finally, an unbalanced load was used to validate the performance of the neutral current compensation.The proposed shunt APF topology presented in this paper is simulated with MATLAB/Simulink sim power system toolbox.

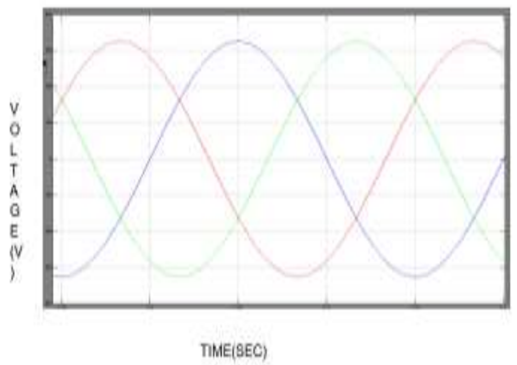

Fig.3 hree phase source voltage of open loop

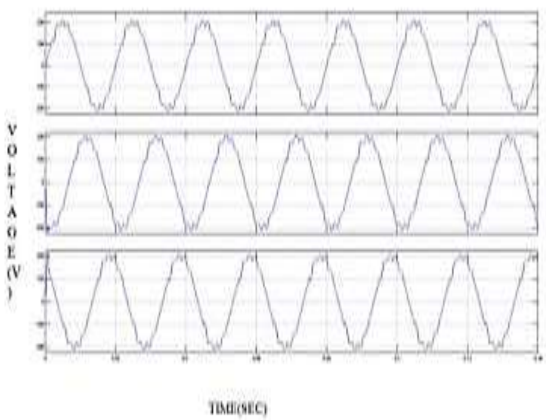

Fig.4 results of three phase load voltage of open loop.

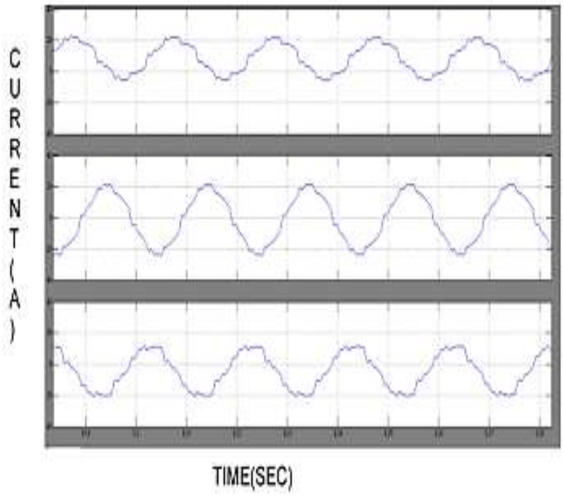

Fig.5 hree phase output load current of open loop and the value of the three phase load current is 20A

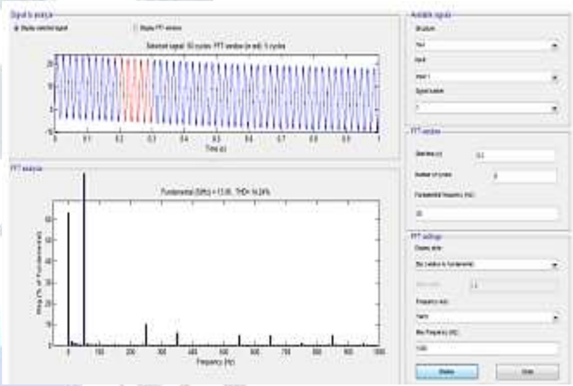

Fig.6 THD display of open loop

V. CONCLUSION

he proposed Predictive controller consists of the inner current loop and outer voltage loop controller. For the inner loop, the predictive control algorithm is employed to generate proper switching functions for the VSC-Based shunt active power filter and to achieve the current and voltage regulation. The simulation results shows that the proposed model can compensate the reactive power flow thereby improving the system response and decrease the THD.

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